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## PATENT SPECIFICATION

DRAWINGS ATTACHED

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### COMPLETE SPECIFICATION

#### Method of and apparatus for Fabricating Self-Lubricating Articles or Components, and Articles or Components made by the method

I, GERT DEVENTER, a German citizen, of Hiltensperger Strasse 4, Munich, Germany, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of and apparatus for fabricating self-lubricating articles or components which comprise a colloidal solid lubricant incorporated in a powder metal matrix, and to articles or components made by the method.

Such articles are at present fabricated as a graphite-containing metal powder moulding comprising a consolidated mass of a metal powder or powders comprising mixed grain sizes up to about 60 microns and colloidal graphite, the mixture having been sintered and compressed whereby the metal structure is stabilised with the colloidal graphite trapped under pressure in the interstices of the metal matrix, the moulding being machined to the shape and dimensions of the required article or component. The production of such mouldings is described in United States Specification No. 2,974,039 and British Specification Nos. 892,846 and 892,847. The principal metal powder comprises iron, copper, aluminium and/or nickel, separately or in combination, to which may be added secondary metal powders such as zinc, tin, lead and cadmium, alone or in combination.

The present invention has for an object to reduce the cost of such articles and components by using the special self-lubricating material to provide only the bearing or wearing surface of the article or component, the self-lubricating material being bonded as a

layer on a support comprising a metal backing sheet or strip which provides the required mechanical support for the self lubricating layer.

From one aspect, the invention consists in a method for the manufacture of self-lubricating articles or components comprising intimately mixing one or more metal powders, comprising mixed grain sizes of up to 60 microns, with a powdered solid lubricant comprising colloidal graphite and/or colloidal molybdenum disulphide and/or colloidal boron nitride (the lubricant occupying 3% to 50% of the total volume), loosely spreading the powder mixture in a layer on the surface of a metal backing strip, heating the backing strip, with the powder layer thereon, in an atmosphere which avoids undesirable oxidation or reaction with the powder, to a sintering temperature below the melting point of the principal metal powder constituent, rolling and further heating the strip with the powder layer thereon to produce an annealed dense and coherent layer, comprising the sintered metal matrix with particles of the solid lubricant incorporated in the interstices of the matrix, which is bonded to the surface of the metal backing strip. The composite strip can be submitted to fabricating operations, such as blanking, forming and machining, to produce bearing shells, thrust washers, or other components.

In one embodiment of the method according to the invention, a strong metal backing strip, for example, of mild steel, is cleaned and, if necessary, copper plated prior to loosely spreading the powder mixture on the surface of the metal backing strip to the desired thickness. The powder mixture may com-

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prise 75% to 80% of copper, 10% to 15% of tin and 8% to 12% of colloidal grapsite, the percentages being given by weight. The backing strip, with the powder thereon, is heated in an atmosphere which avoids undesirable oxidation or reaction with the powder, to a sintering temperature below the equilibrium solidus of the alloy formed from the metal powder mixture concerned, for example between 600° C and 750° C, and, after withdrawal from the furnace and being cooled, is then rolled to compact the powder layer. The composite strip is then submitted to a further heat treatment to develop the bond between the metal powder grains, and between the metal powder grains and the backing strip, and to relieve the stresses in the metal powder matrix. The composite strip can then be submitted to conventional fabricating operations, such as blanking, forming and machining, in order to produce bearing shells, thrust washers or other components.

From another aspect the invention consists in an article or component having a self-lubricating surface and comprising a sheet metal backing on to at least one surface of which is roll-bonded a substantially dense and coherent layer, comprising a sintered metal matrix the interstices of which contain particles of a colloidal solid lubricant, the lubricant occupying 3% to 50% of the total volume of the layer.

The invention further consists in an apparatus for carrying out the process.

In order that the invention may be more clearly understood, reference will now be made to the accompanying drawing, in which:—

Figure 1 is a diagrammatic side view of an apparatus for carrying out the process of this invention.

Figure 2 is a section along the line A—A in Figure 1.

Figure 3 is a plan view of the spreading arrangement, with the hopper removed.

Figure 4 is a perspective view of a shell bearing according to this invention.

Referring to the drawing, a mild steel backing strip 1 is fed from the coil 1a by driven straightening rollers 2, and, after being fed past the spreading device generally indicated by 3 where the powder mixture 7 is loosely spread on the surface of the strip, passes through a sintering furnace 4. After leaving the sintering surface, the strip with the powder layer 7 thereon is rolled between rollers 5 to consolidate the powder into a compact layer on the surface of the metal backing strip. After leaving the rollers 5 the composite strip passes through an annealing furnace 6. The composite strip is drawn from the annealing furnace by pull-out rollers 8 and may then be cut into desired lengths, wound on to a roll or directly fed to machines for fabricating the components to be made.

In the spreading device 3 the powder mix-

ture 7 is fed to the upper surface of the strip 1 from a hopper 9. The strip 1 moves in the spreading device on an endless belt 10 which is wider than the strip 1 and is supported by the rigid table 11. The strip is located laterally with respect to the hopper by means of inverted L-shaped guides 12 supported above the belt 10. The hopper 9 which is carried by the guides 12, has an outlet 9a which is of a depth to provide a layer of powder 7 on the strip exceeding the thickness of the required loosely spread layer. The side walls of the guides 12 keep the powder 7 on the strip, leaving side zones thereof uncovered by the powder. The powder layer is spread to cover these side zones and to produce the powder layer of the required thickness by a generally V-shaped spreading blade or plough 13, excess powder being deflected over the sides of the metal backing strip 1 and on to the surface of the belt 10. The powder which falls on to the belt is discharged into a collecting device 14 for feeding back to the hopper 9.

The furnace 4, having refractory walls 15, may be heated in any suitable manner by heating means generally indicated at 16. The metal strip with the powder thereon passes through a muffle 17 in the furnace having walls of a heat-resisting alloy, such as "Inconel" (Registered Trade Mark), the muffle containing an atmosphere which avoids undesirable oxidation or reaction with the powder, for example an atmosphere of cracked ammonia, which may be fed into the muffle via the inlet 18. Excess gas is burnt at the ends of the muffle. The outlet end of the muffle is provided with a water-cooled chill plate 19 beyond the end of the furnace chamber. The inlet end of the muffle may also have a water-cooling passage 20 therearound.

The furnace should be arranged so that the temperature of the powder will not be raised too quickly to the sintering temperature. The time required to reach the sintering temperature should be at least 1 minute, preferably not less than 1½ minutes, in order to avoid cracking of the powder layer. To achieve this the furnace chamber can conveniently be about 9 feet long when the metal strip is fed at a speed of 3 feet per minute. The heating means 16 may be divided into sections which may be separately controlled to regulate the rate of rise of temperature. Any powder which may fall off the strip in the muffle is collected in a box 21 in the floor of the muffle, the bottom of which can be opened periodically to empty the collected powder. The box 21 should be located at a position where the temperature is not sufficiently high to melt the powder. The strip after being maintained at the sintering temperature for a short time then passes into the cooling zone and over the chill plate 19, and is cooled substantially before leaving the muffle.

The strip 1 with the sintered powder 7

thereon is then rolled cold by the rollers 5 so as to reduce the thickness of the powder layer and to improve the metal-to-metal contact between the metal powder grains, and between the metal powder grains and the backing strip, by disruption of the solid lubricant film therebetween, whereby to produce a substantially fully compacted layer. The reduction in the thickness of the powder layer may be about 80%.

At this stage the bond between the metal powder grains, and between the grains and the backing strip, is weak, and the compacted layer can be easily scratched and scraped off the backing strip.

The rolled strip is then passed through an annealing furnace 6 which may be similar to the sintering furnace 4, in which the compacted powder layer is again heated to about the same temperature as in the sintering furnace 4. This annealing treatment develops the bond between the metal powder grains, and between the grains and the backing strip, and relieves the stresses within the compacted layer. Upon leaving the annealing furnace the metal grains have been firmly welded to each other and to the backing strip, producing a substantially dense and coherent layer, comprising a sintered metal matrix with the solid lubricant incorporated in the interstices of the matrix, which is bonded to the surface of the metal backing strip. The layer is resistant to scratching and the composite strip will withstand fabricating operations, to produce, for example, shell bearings such as shown in Figure 4.

If the sintered powder layer on the backing strip is rolled hot, instead of cold, the separ-

ate annealing furnace may be dispensed with provided the rolling is effected in a reducing atmosphere. The rolls may, for example, be located in the sintering furnace. It is important however, that the stresses in the compacted layer should be relieved.

In one particular example, the powder mixture comprises 79½% copper, 12½% tin and 8% colloidal graphite, the percentages being given by weight. The metal powders have mixed grain sizes of from 5 to 60 microns and are preferably of irregular shape. The metal powders and graphite are intimately mixed before being fed to the hopper 9. The mild steel strip 1 may be about 0.050 thick and has its surface, on which the powder is to be spread, copper plated. The loose powder layer may have a thickness of about 0.200", which after sintering and rolling is reduced to a thickness of about 0.040". The strip and powder are heated in the sintering furnace to about 725° C in about 2½ minutes, and are held at this temperature for about ½ minute before being quickly cooled by passing over the chill plate 19. The temperature to which the powder is heated in the annealing furnace 6 is also 725° C.

Similar sintering and annealing temperatures are suitable for a powder mixture of 77½% copper, 12½% tin and 10% colloidal graphite, percentages being given by weight.

Other compositions of powder mixtures are possible. Various compositions which may be used are shown in the following Table. The figures in brackets refer to weight percentages, except where otherwise stated, and are maxima.

Group	Principal Metal Powder	Secondary Additions	Lubricants
1	Cu, Fe, Al, separately or combined, or further combined with.....	Zn, Sn, Pb, Cd, Sb, Be, Mn, separately or in any combination provided that the total does not exceed 15% with optionally up to 5% Indium in addition.	Graphite, Bn, MoS <sub>2</sub> or any combination of these provided the total lies between 3—50% by volume of the finished compact.
2	Cu, in combination with.....	Be (3) Sn (15) Zn (50) Ni (30) P (1) Si (15) Ag (0.1) Te (1) Cr (1) Pb and/or In (18) separately or in any combination but in total not exceeding 60% of the total metallic content.	Ditto
3	Fe, in combination with.....	Ni (5), Cr (2), Mn (2) Nb (1) Ti (1) Mo (1), Si (0.5), P (1), Pb and/or In (15) separately or in any combination but in total not exceeding 25% of the total metallic content.	Ditto
4	Al, in combination with.....	Ni (2), Si (15), Sn (50), Zn (12), Mg (12), Pb and/or In (20) separately or in any combination but in total not exceeding 50% of the total metallic content.	Ditto
5	Ni, separately or in combination with.....	Cu (40), Si (5), Mn (3), Mg (1), Sn (5), Fe (2), Pb and/or In (15) separately or in any combination but not in total exceeding 60% of the metallic content.	Ditto

5 The backing strip should be made or plated with a metal which bonds with the metal grains of the powder mixture. For a mixture of which aluminium is the principal metal powder, the backing strip is preferably of aluminium.

10 If high percentages of lubricants (for example 12% or more) are to be incorporated, the colloidal lubricant grains (of about 1 micron) are first agglomerated by cold pressing, the agglomerate being comminuted to produce granules of about 200 to 500 microns which are then mixed with the metal powder 15 or powders.

The backing strip can be provided with a compacted layer on both surfaces by submit-

ting a composite strip having a compacted layer on one surface to a second treatment to provide a compacted layer on the other surface of the backing strip.

WHAT I CLAIM IS:—

1. The method for the manufacture of self-lubricating articles or components comprising intimately mixing one or more metal powders, 25 comprising mixed grain sizes of up to 60 microns, with a powdered solid lubricant comprising colloidal graphite and/or colloidal molybdenum disulphide and/or colloidal boron nitride (the lubricant occupying 3% to 30 50% of the total volume), loosely spreading the powder mixture in a layer on the surface of a metal backing strip, heating the backing

strip, with the powder layer thereon, in an atmosphere which avoids undesirable oxidation or reaction with the powder, to a sintering temperature below the melting point of the principal metal powder constituent, rolling and further heating the strip with the powder layer thereon to produce an annealed dense and coherent layer, comprising the sintered metal matrix with particles of the solid lubricant incorporated in the interstices of the matrix, which is bonded to the surface of the metal backing strip.

2. The method as claimed in claim 1, wherein after heating to the sintering temperature, the strip and powder layer are cooled before rolling, and the rolled composite strip is submitted to a further heat treatment to develop the bond between the metal powder grains, and between the metal powder grains and the backing strip, and to relieve the stresses in the sintered metal matrix.

3. The method as claimed in claim 1 or 2, which consists in heating the powder layer at a rate such that the time required to reach the sintering temperature is at least 1 minute.

4. The method as claimed in claim 1, 2 or 3, wherein the rolling produces a reduction in the thickness of the loose powder layer of about 80%.

5. Method for the manufacture of self-lubricating articles which consists in intimately mixing 75% to 80% by weight of powdered copper and 10% to 15% by weight of powdered tin, said metal powders comprising mixed grain sizes of up to 60 microns, with 8% to 12% by weight of colloidal graphite, loosely spreading the powder mixture in a layer on the copper-plated surface of a mild steel backing strip, heating said backing strip with the powder layer thereon in a reducing atmosphere to a temperature of between 600°C and 750°C, preferably about 725°C in a time of from 1 to 3 minutes, cooling the strip with the powder layer thereon, rolling the strip with the powder layer thereon between rollers to reduce the thickness of the layer to about 20% of its original thickness, heating the rolled composite strip to a temperature to develop the bond between the metal powder grains and between the metal powder grains and the backing strip, and to relieve the stresses in the metal powder matrix, whereby to produce an annealed dense and coherent layer, comprising the copper-tin sintered metal matrix with the colloidal graphite incorporated in the interstices of the matrix, which is bonded to the copper-plated surface of the backing strip.

6. The method for the manufacture of self-lubricating articles or components as claimed

in any of the preceding claims, substantially as hereinbefore described.

7. An article or component having a self-lubricating surface and comprising a sheet metal backing on to at least one surface of which is roll-bonded a substantially dense and coherent layer, comprising a sintered metal matrix the interstices of which contain particles of a colloidal solid lubricant, the lubricant occupying 3% to 50% of the total volume of the layer.

8. An article or component as claimed in claim 7, comprising a mild steel sheet backing having at least one surface copper plated and having roll-bonded thereto a layer of sintered metal matrix comprising 75% to 80% by weight of copper and 10% to 15% by weight of tin, with 8% to 12% by weight of colloidal graphite incorporated in the interstices of the metal matrix.

9. An article or component as claimed in claim 7 or 8, wherein the roll-bonded layer comprises 79½% by weight of copper, 12½% by weight of tin, and 8% by weight of colloidal graphite.

10. An article or component as claimed in claim 7 or 8, wherein the roll-bonded layer comprises 77½% by weight of copper, 12½% by weight of tin, and 10% by weight of colloidal graphite.

11. An article or component having a self-lubricating surface which has been made by the method claimed in any one of claims 1 to 6.

12. Apparatus for the manufacture of self-lubricating articles or components according to the method claimed in claim 1, comprising a powder spreading device for loosely spreading the powder mixture in an even layer over the surface of the metal backing strip as it moves therethrough, said spreading device including an endless conveyor belt, of which the upper run supports the metal backing strip, two L-shaped guides extending above and longitudinally of the conveyor belt to define a guideway for the metal backing strip, a powder hopper above said guides and arranged to feed powder between said guides to a predetermined thickness, and a plough arranged downstream of said hopper and adapted to spread the powder on the metal strip to a thickness less than said predetermined thickness and to deflect the excess powder on to said conveyor belt; a sintering furnace including a muffle, heating means comprising separate sections for regulating the heat along said muffle, and a chill plate at the end of said muffle for chilling the metal strip and the powder layer thereon; compacting rolls for compacting the powder layer on the metal strip; an annealing

furnace; and means for feeding the metal backing strip successively through said spreading device, said sintering furnace, said compacting rolls and said annealing furnace.

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